Benefits of Water-Cooled Systems vs. Air-Cooled Systems for Air-Conditioning Applications

Kavita A. Vallabhaneni
U. S. Government commitment to reduce greenhouse gas emissions can have a significant impact on HVAC system consideration.
Kyoto Conference on Global Warming

- International effort to control greenhouse gas emissions
- Greenhouse gases include:
  - Carbon Dioxide (CO₂)
  - Methane (CH₄)
  - Nitrous Acid (N₂O)
  - Hydrofluorocarbons (HFC’s)
  - Perfluorocarbons (PFC’s)
  - Sulfur Hexafluorides (SF₆)
U. S. Commitment to Kyoto Conference

- Kyoto Protocol signed by President Bill Clinton in October, 1997
  - Committed U. S. to reduce greenhouse gas emissions to 7% below 1990 levels by 2012
- President Bush rejected the Kyoto Protocol and has argued that the treaty was wrong to exempt developing nations like China and India, and would hurt the U. S. economically.
- U. S. has chosen another policy. But we have the same targets, and we have to meet the same problems.

Total GHG emissions are 1,883 million metric tons carbon equivalent.
U. S. Greenhouse Gas Emissions

Carbon Dioxide ($\text{CO}_2$) emissions account for approximately 85% of the U. S. greenhouse gas emissions.
Major CO$_2$ Emissions Sources

- Transportation Industry
- Heavy Industry
- Utility Industry
Major CO₂ Emission Sources
Utility Industry

- Fossil Fuel Burning Power Plants
  - Produce 55% of U. S. electricity
  - Addition of exhaust gas scrubbers not economically viable for most plants
  - Only 16% of Power Plants have exhaust scrubbers.
US Gov’t Plan to Reduce CO₂ Emissions from Power Plants

- Convert to less carbon intensive fuels or non-carbon fuels
  - Taxation of carbon fuels
  - Regulation of emissions for new plants
- Reduce energy demand
  - New energy-saving technologies
- Improve efficiency of equipment and systems
Fossil Fuel Burning Power Plants

Air-conditioning systems drive many power plant peak loads and have been identified as an energy reduction opportunity.
U. S. Actions Impacting HVAC Systems and Equipment

- ASHRAE Standard 90.1 as basis for energy efficiency for commercial buildings.
Energy Saving System Designs...

...our Environmental Responsibility
Basic Air-Conditioning System

- Large Buildings (> 400 tons)
  - Water cooled systems provide clear-cut economic and environmental justification.

- Mid-size Buildings (200-400 tons)
  - Air cooled systems may offer first cost incentive to sacrifice energy efficiencies of water cooled systems.
Theoretical Building Profile

- **Building load**
  - 400 tons

- **Building Configuration**
  - Square with five (5) floors
  - One (1) air handling fan/floor

- **Air Volume**
  - 350 CFM/ton
  - 3 ½” w. g. T. S. P.
400 Ton System Comparisons

- Chiller systems:
  - Air-Cooled Chiller
  - Centrifugal Chiller

- Packaged systems:
  - Roof-Top Units
  - Self-Contained Units
400 Ton System Comparisons

- Compare five components
  - System energy requirements
  - Installed cost
  - Annual energy cost
  - Annual water usage & cost
  - Payback analysis
## System Energy Requirements

- **400 Ton Air-Cooled System**

<table>
<thead>
<tr>
<th>Component</th>
<th>KW/Unit</th>
<th>Total KW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>406.00</td>
<td>406.00</td>
</tr>
<tr>
<td>Condenser Fans</td>
<td>62.50</td>
<td>62.50</td>
</tr>
<tr>
<td>Air Handling Units</td>
<td>22.37</td>
<td>111.85</td>
</tr>
<tr>
<td>Chilled H₂O pump</td>
<td>14.92</td>
<td>14.92</td>
</tr>
<tr>
<td><strong>Total KW</strong></td>
<td></td>
<td><strong>595.27</strong></td>
</tr>
</tbody>
</table>

- **KW/Ton = 595.27/400 = 1.49 KW/ton**
System Energy Requirements

- 400 Ton Centrifugal Chiller System

<table>
<thead>
<tr>
<th></th>
<th>KW/Unit</th>
<th>Total KW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>220.0</td>
<td>220.00</td>
</tr>
<tr>
<td>Air Handling Units</td>
<td>22.37</td>
<td>111.85</td>
</tr>
<tr>
<td>Chilled H₂O pump</td>
<td>14.92</td>
<td>14.92</td>
</tr>
<tr>
<td>Condenser H₂O pump</td>
<td>11.19</td>
<td>11.19</td>
</tr>
<tr>
<td>Cooling tower fan</td>
<td>18.65</td>
<td>18.65</td>
</tr>
<tr>
<td><strong>Total KW</strong></td>
<td></td>
<td><strong>376.61</strong></td>
</tr>
</tbody>
</table>

- KW/Ton = 376.61/400 = 0.94 KW/ton
Theoretical 400 Ton System Comparisons

- **Chiller systems**
  - Air-cooled chiller system ...... 1.49 KW/ton
  - Centrifugal chiller system ...... 0.94 KW/ton
## System Energy Requirements

- **400 Ton Roof-Top System**: (5) 80 Ton Units

<table>
<thead>
<tr>
<th></th>
<th>KW/Unit</th>
<th>Total KW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>74.65</td>
<td>373.25</td>
</tr>
<tr>
<td>Air handling fan</td>
<td>29.84</td>
<td>149.20</td>
</tr>
<tr>
<td>Condenser fan</td>
<td>8.60</td>
<td>43.00</td>
</tr>
<tr>
<td><strong>Total KW</strong></td>
<td></td>
<td><strong>565.45</strong></td>
</tr>
</tbody>
</table>

- **KW/Ton** = \( \frac{565.45}{400} = 1.42 \text{ KW/ton} \)
System Energy Requirements

- 400 Ton Self-Contained System: (5) 80 Ton Units

<table>
<thead>
<tr>
<th>Component</th>
<th>KW/Unit</th>
<th>Total KW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>63.12</td>
<td>315.60</td>
</tr>
<tr>
<td>Air handling fan</td>
<td>22.37</td>
<td>111.85</td>
</tr>
<tr>
<td>Condenser H₂O pump</td>
<td>11.19</td>
<td>11.19</td>
</tr>
<tr>
<td>Cooling tower fan</td>
<td>18.75</td>
<td>18.75</td>
</tr>
<tr>
<td><strong>Total KW</strong></td>
<td></td>
<td><strong>457.39</strong></td>
</tr>
</tbody>
</table>

- KW/Ton = 457.39/400 = 1.14 KW/ton
System Energy Comparison

- Chiller systems
  - Air-cooled chiller system ...... 1.49 KW/ton
  - Centrifugal chiller system ...... 0.94 KW/ton

- Packaged systems
  - Roof-top units ..................... 1.42 KW/ton
  - Self-Contained units ............. 1.14 KW/ton
Basic HVAC System Options

- Water-cooled systems
  - More energy-efficient than air-cooled systems
  - Support environmental efforts to control greenhouse gas emissions
Installed Cost Estimate Sources

- Air Cooled Chiller ........ $350/Tr x 1.50
- Centrifugal Chiller ........ $250/Tr x 1.50
- Roof Top Units ............ $550/Tr x 1.25
- Self Contained Units ....... $400/Tr x 1.50
- Air Handling Units ......... $1.00/CFM x 1.25
- Cooling Towers ............ $45/Tr x 1.50
- Pump/Piping ............... Means Mech. Est.
Installed Cost Estimate
Air Cooled Chiller System

* 400 ton air cooled chiller …….$210,000
* (5) 28,000 CFM air handlers .$175,000
* 1000 LF chilled water piping..$ 67,000
* Chilled water pump ………..$ 3,600

* Total installed cost …………..$455,600
Installed Cost Estimate
Centrifugal Chiller System

- 400 ton centrifugal chiller ............ $150,000
- 400 ton cooling tower ................. $ 27,000
- (5) 28,000 CFM air handlers .......... $175,000
- 1000 LF chilled H2O piping ........... $ 67,000
- 400 LF condenser H2O piping ...... $ 26,800
- Chilled water pump ..................... $ 3,600
- Condenser water pump ............... $ 4,000
- Mechanical equipment room .......... $ 45,000

- Total Installed Cost .................... $498,400
Installed Cost Estimate
Roof-Top Unit System

- (5) 80 ton roof top units ....

- Installed cost ......................... $275,000
Installed Cost Estimate
Self-Contained Unit System

- (5) 80 ton self-contained units .. $240,000
- Closed Circuit Cooling Tower …$ 54,000
- Condenser water pump ............$ 4,000
- Condenser water piping ............$ 26,800

- Installed cost ....................$324,800
## Installed Cost Summary

<table>
<thead>
<tr>
<th>Chiller Systems</th>
<th>Installed Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-Cooled Chiller</td>
<td>$455,600</td>
</tr>
<tr>
<td>Centrifugal Chiller</td>
<td>$498,400</td>
</tr>
<tr>
<td>Package Systems</td>
<td></td>
</tr>
<tr>
<td>Roof-Top</td>
<td>$275,000</td>
</tr>
<tr>
<td>Self-Contained</td>
<td>$324,800</td>
</tr>
</tbody>
</table>
System Energy Cost Assumptions

- 1800 Equivalent Full Load Hours per Year
- $0.06 per KW-Hour
- $12 per KW Demand Charge for 6 Months
## Annual Energy Cost Comparison

<table>
<thead>
<tr>
<th>System</th>
<th>Total KW</th>
<th>Annual Energy Cost</th>
<th>Annual Demand Cost</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chiller System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air-Cooled Chiller</td>
<td>595.27</td>
<td>$64,289</td>
<td>$42,860</td>
<td>$101,149</td>
</tr>
<tr>
<td>Centrifugal Chiller</td>
<td>376.61</td>
<td>$40,674</td>
<td>$27,116</td>
<td>$67,790</td>
</tr>
<tr>
<td><strong>Packaged Systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof-Top</td>
<td>565.45</td>
<td>$61,069</td>
<td>$40,712</td>
<td>$101,781</td>
</tr>
<tr>
<td>Self-Contained</td>
<td>457.39</td>
<td>$49,398</td>
<td>$32,932</td>
<td>$82,330</td>
</tr>
</tbody>
</table>
# System Cost Summary

<table>
<thead>
<tr>
<th></th>
<th>Installed Cost</th>
<th>Annual Energy Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chiller System</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air-Cooled Chiller</td>
<td>$455,600</td>
<td>$107,149</td>
</tr>
<tr>
<td>Centrifugal Chiller</td>
<td>$498,400</td>
<td>$67,790</td>
</tr>
<tr>
<td><strong>Packaged System</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof-top</td>
<td>$275,000</td>
<td>$101,781</td>
</tr>
<tr>
<td>Self-contained</td>
<td>$324,800</td>
<td>$82,330</td>
</tr>
</tbody>
</table>
Water Usage

- Water cooled systems recycle 95% of the total water
- The remaining 5% is lost to evaporation & bleed.
- A small portion of the water is bled from the system to control the build-up of impurities

Bleed Rate = \frac{\text{Evaporation Rate}}{\text{Cycles of Concentration} - 1}
Water Usage and Cost (400 ton sample system)

Evaporation Rate = 3.0 GPM/100 ton

= 12.0 GPM/400 ton system
Water Usage and Cost (400 ton sample system)

Evaporation Rate = 3.0 GPM/100 ton
= 12.0 GPM/400 ton system

Bleed Rate = 12.0 GPM
4 cycles –1

Bleed Rate = 4.0 GPM
Water Usage and Cost
(400 ton sample system)

Evaporation Rate = 3.0 GPM/100 ton
   = 12.0 GPM/400 ton system

Bleed Rate = 12.0 GPM
   4 cycles – 1
Bleed Rate = 4.0 GPM

Consumption = Evaporation + Bleed
   = 12.0 GPM + 4.0 GPM
   = 16.0 GPM
Water Usage and Cost (400 ton sample system)

- **Annual Water Consumption**
  - 16.0 GPM x 60 min/hr x 1800 eq FLH
  - 1,728,000 gallons/year

- **Annual Water and Sewer Cost**
  - 1,728,000 gallons x $3.00/1000 gal
  - $5,184
Water Quality and Control Cost Considerations

- Water-cooled systems require chemical treatment to control scale/corrosion and biological growths.
- These costs must be included in a cost analysis of water-cooled and air-cooled systems.
Annual Water Treatment Costs
(400 ton sample system)

- Full Service Water Treatment
  - Average annual program costs - $1.00/ton/month
  - 400 Tr x $1.00/ton/month x 6 month = $2400/year
## Annual Water Cost Estimate (400 ton sample system)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Consumption</strong></td>
<td>$5,184</td>
</tr>
<tr>
<td><strong>Water Treatment</strong></td>
<td>$2,400</td>
</tr>
<tr>
<td><strong>Annual Water Cost</strong></td>
<td>$7,584</td>
</tr>
</tbody>
</table>
## System Cost Summary

<table>
<thead>
<tr>
<th></th>
<th>Installed Cost</th>
<th>Annual Energy Cost</th>
<th>Annual Water Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chiller Systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Cooled Chiller</td>
<td>$455,600</td>
<td>$107,149</td>
<td>N/A</td>
</tr>
<tr>
<td>Centrifugal Chiller</td>
<td>$498,400</td>
<td>$67,790</td>
<td>$7,584</td>
</tr>
<tr>
<td><strong>Packaged System</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof-Top Units</td>
<td>$275,000</td>
<td>$101,781</td>
<td>N/A</td>
</tr>
<tr>
<td>Self-Contained</td>
<td>$324,800</td>
<td>$82,330</td>
<td>$7,584</td>
</tr>
</tbody>
</table>
## System Cost Summary

<table>
<thead>
<tr>
<th></th>
<th>Installed Cost</th>
<th>Annual Energy Cost</th>
<th>Annual Water Cost</th>
<th>Payback Yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chiller Systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air-Cooled Chiller</td>
<td>$455,600</td>
<td>$107,149</td>
<td>N/A</td>
<td>Base</td>
</tr>
<tr>
<td>Centrifugal Chiller</td>
<td>$498,400</td>
<td>$67,790</td>
<td>$7,584</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Packaged system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof-Top Units</td>
<td>$275,000</td>
<td>$101,781</td>
<td>N/A</td>
<td>Base</td>
</tr>
<tr>
<td>Self-Contained</td>
<td>$324,800</td>
<td>$82,330</td>
<td>$7,584</td>
<td>4.2</td>
</tr>
</tbody>
</table>
HVAC System Considerations

Cost analysis must consider the economic impact that environmental and electric power generation issues will have on energy prices in the near future.
Projected Energy Prices for Commercial Market*

- Projected Energy Price Increase ($P_V$)
  - 2025 Projected Increase ........ + 32.05%

* per 2005 Energy Information Administration (EIA) report
## 2025 Simple Payback Analysis

<table>
<thead>
<tr>
<th></th>
<th>Installed Cost</th>
<th>Annual Energy Cost</th>
<th>Annual Water Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chiller System</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air-Cooled Chiller</td>
<td>$455,600</td>
<td>$141,490</td>
<td>N/A</td>
</tr>
<tr>
<td>Centrifugal Chiller</td>
<td>$498,400</td>
<td>$89,517</td>
<td>$7,584</td>
</tr>
<tr>
<td><strong>Packaged System</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof-Top Units</td>
<td>$275,000</td>
<td>$134,402</td>
<td>N/A</td>
</tr>
<tr>
<td>Self-Contained</td>
<td>$324,800</td>
<td>$108,717</td>
<td>$7,584</td>
</tr>
</tbody>
</table>
### 2025 Simple Payback Analysis

<table>
<thead>
<tr>
<th>Chiller System</th>
<th>Installed Cost</th>
<th>Annual Energy Cost</th>
<th>Annual Water Cost</th>
<th>Payback Yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-Cooled Chiller</td>
<td>$455,600</td>
<td>$141,490</td>
<td>N/A</td>
<td>Base</td>
</tr>
<tr>
<td>Centrifugal Chiller</td>
<td>$498,400</td>
<td>$89,517</td>
<td>$7,584</td>
<td>0.75</td>
</tr>
<tr>
<td>Packaged System</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof-Top Units</td>
<td>$275,000</td>
<td>$134,402</td>
<td>N/A</td>
<td>Base</td>
</tr>
<tr>
<td>Self-Contained</td>
<td>$324,800</td>
<td>$108,717</td>
<td>$7,584</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Deregulation of Electric Power Generation Industry
Electric Power Industry

Generation  Transmission  Distribution
Deregulation

- Changed since 2001
- Consolidation efforts are taking place
  - Con Edison merging with Excelon
  - Fewer number of companies = higher prices for the customer
- Some utilities are modeling Demand Response models
Energy Saving System Designs....

...our

Environmental Responsibility
Energy Saving System Designs....

...our

Fiscal Responsibility
Process Cooling Wise Rule 1. Installing energy efficient chillers and refrigeration systems can save 1.2% of a facility’s total energy use with an average simple payback of 23 months.

Process Cooling Wise Rule 2. Free cooling with cooling tower water can reduce a facility's total energy use by about 1% with an average simple payback of 14 months.
EPA Climate Wise Program – Wise Rules to Energy Efficiency

- **Process Cooling Wise Rule 3.** Free cooling can reduce cooling system energy use by as much as 40% depending on location and load profile.

- **Process Cooling Wise Rule 4.** Increasing chilled water temperature by 1°F reduces chiller energy use by 0.6% to 2.5%.
EPA Climate Wise Program – Wise Rules to Energy Efficiency

- **Process Cooling Wise Rule 5.** Reducing condenser pressure by 10 psi can decrease refrigeration system energy use per ton of refrigeration by about 6%.

- **Process Cooling Wise Rule 6.** For each degree decrease in condenser cooling water temperature, until optimal water temperature is reached, there is a decrease in chiller energy use by up to 3.5%.
There's simply no substitute for raw (chiller) efficiency.
Equipment Cost Comparison*

Centrifugal Chiller: First Cost...

$250/ton

Means Mechanical Cost Data
Equipment Cost Comparison*

Centrifugal Chiller First Cost...

$250/ton

Means Mechanical Cost Data

Cooling Tower First Cost...

$45/ton
Energy Saving Tip

Lower the design condenser water temperature
ARI Nominal Condenser Water Rating Condition

3 GPM/Ton

10°F Temperature Rise

85°F Condenser Water
Cooling Towers can be economically selected to provide condenser water temperatures within 4°F or less of the ambient wet bulb temperature.
## Effect of Condenser Water Temperature on Chiller Energy

<table>
<thead>
<tr>
<th>CW Temp</th>
<th>Typ Chiller Energy</th>
<th>Energy Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>85°F</td>
<td>0.570 kW/ton</td>
<td>Base</td>
</tr>
<tr>
<td>83°F</td>
<td>0.542 kW/ton</td>
<td>5%</td>
</tr>
<tr>
<td>80°F</td>
<td>0.524 kW/ton</td>
<td>8%</td>
</tr>
<tr>
<td>75°F</td>
<td>0.484 kW/ton</td>
<td>15%</td>
</tr>
<tr>
<td>70°F</td>
<td>0.450 kW/ton</td>
<td>21%</td>
</tr>
</tbody>
</table>
Rule of Thumb for Saving Chiller Energy

Chiller energy is reduced 2% for every 1°F of reduced condenser water temperature.
Typical Office Building

500 Ton System
Operating Season
8 Months/Year
2,500 Equiv. Full Load Hours
$0.08/kWH Energy Rate
$10/kW Demand Charge
System Economics with Energy Saving Cooling Tower

Nominal Cooling Tower Selection
1500 gpm 95/85/78°F
30 HP Fan Motor
System Economics with Energy Saving Cooling Tower

Nominal Cooling Tower Selection…
1500 gpm 95/85/78°F
30 HP Fan Motor

Energy Saving Cooling Tower Selection…
1500 GPM 93/83/78°F
30 HP Fan Motor
System Economics with Energy Saving Cooling Tower

Nominal Cooling Tower Selection...
1500 gpm 95/85/78°F
30 HP Fan Motor

Energy Saving Cooling Tower Selection...
1500 GPM 93/83/78°F
30 HP Fan Motor

First Cost Premium ..............$7800
Chiller Energy Savings with 2°F Colder Condenser Water

Typical Chiller Energy
Based on 85°F Condenser Water:

0.570 kW/ton
Chiller Energy Savings with 2°F Colder Condenser Water

Typical Chiller Energy Based on 85°F Condenser Water: 0.570 kW/ton

Typical Chiller Energy Based on 83°F Condenser Water: 0.542 kW/ton
Chiller Energy Savings with 2°F Colder Condenser Water

Typical Chiller Energy Based on 85°F Condenser Water: 0.570 kW/ton

Typical Chiller Energy Based on 83°F Condenser Water: 0.542 kW/ton

Saves 0.028 kW/ton
Annual Energy Savings with 2°F Colder Condenser Water

Chiller Peak Energy Reduction ..... 0.028 kW/ton  
500 Ton System ....................... 500 Tons  
Equivalent Full Load Hours/Year ... 2,500 Hours  
Energy Cost .......................... x 0.08 $/kWH  
Energy Savings ....................... $2,800  
Demand Savings (0.028kW/ton  
x 500 tons x $10/kW x 8 months) ... $1,120  
Total Annual Energy Savings ... $3,920
Payback Period for 2°F Colder Condenser Water

Cooling Tower First Cost Premium = $7800
Annual Energy Cost Savings = $3920

= 2.0 Year Payback
Total Energy Savings

20 Year System Life
700,000 kWh saved
$78,400 Saved
Energy Saving Tip

Evaluate the additional free cooling hours with low design water temperatures
Additional Free Cooling Energy Savings

250 Ton Winter Load
55°F Building Loop Water
52°F Condenser Water
System Economics with Energy Saving Cooling Tower

Nominal Cooling Tower Selection
1500 gpm 95°/85°/78°F
30 HP Fan Motor
Winter WB = 46.5°F
4007 Hours
System Economics with Energy Saving Cooling Tower

Nominal Cooling Tower Selection
1500 gpm 95°/85°/78°F
30 HP Fan Motor
Winter WB = 46.5°F
4007 Hours

Energy Saving Cooling Tower Selection
1500 gpm 93/83/78°F
30 Hp Fan Motor
Winter WB = 48.41°
4438 Hours
System Economics with Energy Saving Cooling Tower

Nominal Cooling Tower Selection
- 1500 gpm 95°/85°/78°F
- 30 HP Fan Motor
- Winter WB = 46.5°F
- 4007 Hours

Energy Saving Cooling Tower Selection
- 1500 gpm 93/83/78°F
- 30 Hp Fan Motor
- Winter WB = 48.41°F
- 4438 Hours

Additional Energy Savings..$ 4265
Payback Period for 2°F Colder Condenser Water

Cooling Tower First Cost Premium = $7800
Annual Energy Cost Savings
$3920 +$4265
< 1.0 Year Payback
Total Energy Savings

20 Year System Life
1,766,700 kWh Saved
$163,700 Saved
Energy Saving Tip

Take advantage of ambient wet bulb temperatures
# ASHRAE 0.4% Wet Bulb Temperatures

<table>
<thead>
<tr>
<th>Location</th>
<th>Wet Bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore, MD</td>
<td>78°F</td>
</tr>
<tr>
<td>New York, NY</td>
<td>76°F</td>
</tr>
<tr>
<td>Boston, MA</td>
<td>75°F</td>
</tr>
<tr>
<td>Los Angeles, CA</td>
<td>70°F</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>66°F</td>
</tr>
<tr>
<td>Denver, CO</td>
<td>65°F</td>
</tr>
</tbody>
</table>
## ASHRAE 0.4% Wet Bulb Temperatures

<table>
<thead>
<tr>
<th>Location</th>
<th>Wet Bulb</th>
<th>CWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore, MD</td>
<td>78°F</td>
<td>85°F</td>
</tr>
<tr>
<td>New York, NY</td>
<td>76°F</td>
<td>83.5°F</td>
</tr>
<tr>
<td>Boston, MA</td>
<td>75°F</td>
<td>82.7°F</td>
</tr>
<tr>
<td>Los Angeles, CA</td>
<td>70°F</td>
<td>80.5°F</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>66°F</td>
<td>76.0°F</td>
</tr>
<tr>
<td>Denver, CO</td>
<td>65°F</td>
<td>75.0°F</td>
</tr>
</tbody>
</table>
## ASHRAE 0.4% Wet Bulb Temperatures

<table>
<thead>
<tr>
<th>Location</th>
<th>Wet Bulb</th>
<th>CWT</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore, MD</td>
<td>78°F</td>
<td>85°F</td>
<td>0.57 kW/T</td>
</tr>
<tr>
<td>New York, NY</td>
<td>76°F</td>
<td>83.5°F</td>
<td>0.55 kW/T</td>
</tr>
<tr>
<td>Boston, MA</td>
<td>75°F</td>
<td>82.7°F</td>
<td>0.54 kW/T</td>
</tr>
<tr>
<td>Los Angeles, CA</td>
<td>70°F</td>
<td>80.5°F</td>
<td>0.53 kW/T</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>66°F</td>
<td>76.0°F</td>
<td>0.49 kW/T</td>
</tr>
<tr>
<td>Denver, CO</td>
<td>65°F</td>
<td>75.0°F</td>
<td>0.48 kW/T</td>
</tr>
</tbody>
</table>
# ASHRAE 0.4% Wet Bulb Temperatures

<table>
<thead>
<tr>
<th>Location</th>
<th>Wet Bulb</th>
<th>CWT</th>
<th>Energy</th>
<th>Save</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore, MD</td>
<td>78°F</td>
<td>85°F</td>
<td>0.57 kW/T</td>
<td>Base</td>
</tr>
<tr>
<td>New York, NY</td>
<td>76°F</td>
<td>83.5°F</td>
<td>0.55 kW/T</td>
<td>$2K</td>
</tr>
<tr>
<td>Boston, MA</td>
<td>75°F</td>
<td>82.7°F</td>
<td>0.54 kW/T</td>
<td>$3K</td>
</tr>
<tr>
<td>Los Angeles, CA</td>
<td>70°F</td>
<td>80.5°F</td>
<td>0.53 kW/T</td>
<td>$4K</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>66°F</td>
<td>76.0°F</td>
<td>0.49 kW/T</td>
<td>$6K</td>
</tr>
<tr>
<td>Denver, CO</td>
<td>65°F</td>
<td>75.0°F</td>
<td>0.48 kW/T</td>
<td>$9K</td>
</tr>
</tbody>
</table>
Energy Saving Tips

**Tip #1** – Lower the Design Condenser Water Temperature.

**Tip #2** – Evaluate Additional Free Cooling Hours.

**Tip #3** – Take Advantage of Low Ambient Wet Bulb Temperatures.
Conclusion

- Air-conditioning system evaluations should take the pending impact of environmental issues into consideration.
- Water cooled systems provide the most energy efficient systems and can help protect building owners and operators from uncertainties in electricity pricing.
Benefits of Water-Cooled Systems vs. Air-Cooled Systems for Air-Conditioning Applications

Kavita A. Vallabhaneni